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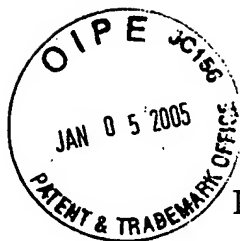
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PATENT
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Makoto IIDA, et al.

Serial No: 10/009,910

Confirmation No. 7347

Filed: December 12, 2001

For: SILICON WAFER, SILICON
EPITAXIAL WAFER, ANNEAL
WAFER AND METHOD FOR
PRODUCING THEM

Art Unit: 1765

Examiner: Matthew J. Song

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APPEAL BRIEF

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Dear Sir:

This is an Appeal from the Examiner's Final Rejection of claims 1-10. The Final Rejection issued on June 24, 2004 and the Notice of Appeal was sent to the Patent and Trademark Office on November 2, 2004 with a Petition for a 2-month extension of time.

REAL PARTY IN INTEREST

The real party in interest is Shin-Etsu Handotai Co., Ltd., Tokyo, Japan.

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RELATED APPEALS AND INTERFERENCES

There are no related appeals or interferences.

STATUS OF CLAIMS

Claims 1-10 are pending. This Appeal is directed to the final rejection of claims 1-10.

STATUS OF AMENDMENTS

A Response to Final Office Action was filed on September 22, 2004 in response to the Final Office Action of June 24, 2004. The Response to Final Office Action makes no amendments but contains arguments with respect to the Final Office Action. An Advisory Action issued on October 8, 2004. The Advisory Action states that Applicants' arguments filed in the Response to Final Office Action on September 22, 2004 have been considered but are not persuasive.

SUMMARY OF THE INVENTION

The present invention relates to a method for producing a silicon single crystal pulled while doping with carbon, and controlling in order to have an N-region over an entire plane of the crystal. The invention also relates to a silicon wafer doped with carbon and having an N-region over an entire plane. This provides a growth technique of a silicon single crystal which makes possible the growth of a single crystal having few grown-in defects and a high IG ability at a high growing rate. There is provided a silicon wafer having an N-region over an entire plane of the crystal and high IG ability.

More specifically, and in accordance with the invention, a silicon single crystal is pulled while doping with carbon and controlling V/G , where V is the crystal pulling rate and G is the crystal solid-liquid interface temperature gradient along a growing axis. The result is an N-region over an entire plane of the crystal. The crystal is pulled at a rate greater than the rate of pulling a silicon single crystal

with no carbon doping. The silicon single crystal is grown in accordance with the Czochralski method. The silicon single crystal is preferably pulled while doping with carbon having a concentration of 0.1 ppma or more and controlling V/G within a range of from 0.183 to 0.177 mm²/K·min.

A silicon single crystal produced by such method may be processed into wafers with the wafers being subjected to heat treatment at a temperature of 600 to 1000°C. Because the wafers are doped with carbon, the formation of oxygen precipitation nuclei at a low temperature in a bulk is accelerated and the wafer having the N-region over the entire surface and having high-level IG ability in the wafer is produced.

The wafers as so produced preferably have a carbon content of 0.1 ppma or more and a nitrogen content of 1×10^{13} number/cm³ or more.

ISSUES

There are several issues to which this Appeal relates. The first such issue is whether Claim 9 is properly rejected under 35 U.S.C. § 112, first paragraph, as failing to comply with the written description requirement. Further issues relate to whether the subject matter of the Claims is unpatentable over various combinations of prior art references under 35 U.S.C. § 103(a).

With respect to the rejections of the Claims as unpatentable over various combinations of the prior art references under 35 U.S.C. § 103(a), such rejections include a rejection of Claims 1 and 5 as unpatentable over U.S. Patent 5,968,264 of Iida et al. (hereafter "Iida") in view of U.S. Patent 6,277,501 of Fujikawa (hereafter "Fujikawa"), the rejection of Claims 2, 6, 9 and 10 as unpatentable over Iida in view of Fujikawa and further in view of U.S. Patent 6,162,708 of Tamatsuka et al. (hereafter "Tamatsuka"), the rejection of Claims 3 and 7 as unpatentable over Iida in view of Fujikawa and further in view of U.S. Patent 5,954,873 of Hourai et al. (hereafter "Hourai"), the rejection of Claims 4 and 8 as unpatentable over Iida in view of Fujikawa and Tamatsuka, and further in view of Hourai, the rejection of

Claims 1, 3, 5, 7 and 9 as unpatentable over Hourai in view of Fujikawa, the rejection of Claims 2, 4, 6, 8 and 10 as unpatentable over Hourai in view of Fujikawa and further in view of Tamatsuka, and the rejection of Claims 1-8 as unpatentable over U.S. Patent 6,641,888 of Asayama et al. (hereafter "Asayama") in view of Iida or Hourai.

GROUPING OF CLAIMS

Claim 1 stands or falls by itself. Claim 1 defines a method for producing a silicon single crystal which is pulled while doping with carbon in order to have an N-region over an entire plane of the crystal.

Claim 2 also stands or falls by itself. While Claim 2 depends from and is similar to Claim 1 in many respects, it defines a separately patentable concept of doping the silicon single crystal with nitrogen as well as carbon.

Claims 3 and 4 stand or fall together. These Claims depend from and further define Claims 1 and 2 respectively in which the doping is carried out with carbon having a concentration of 0.1 ppma or more and the ratio of crystal pulling rate (V) to crystal solid-liquid interface temperature gradient along a growing axis (G) is controlled within a range of 0.183 to 0.177 mm²/K·min.

Claims 5-8 stand or fall together. These Claims depend from and further define Claims 1, 2, 3 and 4 respectively in terms of the wafers being subjected to heat treatment at a temperature of 600 to 1000°C.

Claims 9 and 10 stand or fall together. In addition to reciting apparatus in the form of a silicon wafer, as contrasted with the method of Claims 1-8, Claim 9 recites oxygen precipitation nuclei of 1×10^9 number/cm³ or more, generated by heat treatment, and nitrogen content within the wafer of 1×10^{13} number/cm³ or more.

In addition to the differences noted above, the separate and independent patentability of the groups of Claims discussed above is supported by the fact that there are no less than seven separate rejections of the various Claims based on different groups of references, within the Office Action.

ARGUMENT

1. The Rejection of Claim 9 Under 35 U.S.C. § 112, First Paragraph.

According to the Final Office Action, the recitation “in which oxygen precipitation nuclei of 1×10^9 ” in line 4 thereof has no support in the specification for the oxygen precipitation nuclei. The specification is said to merely teach a BMD density of 1×10^9 , as in the case of page 13 of the specification.

However, such statements indicate a misunderstanding of the present invention. Claim 9 defines a silicon wafer having an N-region over an entire plane, with carbon doping. By doping the crystal with carbon, the formation of oxygen precipitation nuclei can be accelerated by heating treatment at a low temperature of from 600 to 1000° C. This is described at lines 16-23 of page 9, at the last line of page 9 through line 4 of page 10, and at lines 3-8 of page 16 of the specification. More specifically, a wafer having an N-region over an entire plane, with carbon doping, is subjected to heat treatment at a low temperature of from 600 to 1000° C and thereby the oxygen precipitation nuclei can be formed. Then, by subjecting the wafer to heat treatment of, for example, 800°C/4Hr + 1000°C/16Hr., to grow oxygen precipitates, BMD having the density of 1×10^9 number/cm³ or more can be obtained in the wafer. In this connection, see line 21 of page 17 through line 2 of page 18, and lines 10-17 of page 23, of the specification.

Namely, the BMD density is the density of internal micro defects due to oxide precipitates, and the density of BMD is the density of oxide precipitates that oxygen precipitation nuclei grow. In this connection, see line 25 of page 5 through line 10 of page 6 of the specification. Therefore, it is natural that there is oxygen precipitation nuclei of 1×10^9 number/cm³ or more formed by heating treatment at a low temperature of from 600 to 1000° C because the density of BMD that oxygen precipitation nuclei grow is 1×10^9 number/cm³ or more in the wafer, in the present invention.

Therefore, the density of oxygen precipitation nuclei as set forth in claim 9 of the present application is supported in the specification and is the effect of carbon doping. Consequently, claim 9 is submitted to comply with the written description requirement, and withdrawal of the rejection of the claims under 35 U.S.C. § 112, first paragraph, is respectfully requested in view of this explanation.

In the "Response to Arguments" set forth on page 2 of the Advisory Action, it is stated that the above arguments are not persuasive because there is still no explicit teaching that the oxygen precipitation nuclei density is 1×10^9 number /cm³. Applicants' argument is said to be based on there being 1×10^9 number/cm³ of BMD, which is the density of internal micro defects due to oxide precipitates and the density of BMD is the density of oxide precipitates that oxygen precipitates nuclei grow. This reasoning is said to be flawed because Applicants are asserting that each BMD formed is formed from each oxide precipitate, which is not supporting. According to the Examiner's response, each oxide precipitate nuclei could form more than one BMD, so the density of oxygen precipitation nuclei cannot be determined from the density of BMD, which is formed from them. Furthermore, and as stated in the response, BMD is defined as the bulk micro defects due to oxide precipitates, not the oxide precipitate nuclei. There is no defined relationship between BMD density and oxide precipitate nuclei, as Applicants have suggested, and therefore the rejection of Claim 9 on these grounds is said to be maintained.

In response to this, Applicants note however that the Examiner has argued on the assumption that more than one BMD can be formed from one oxygen precipitation nucleus. The assumption itself is mistaken. As above described, the oxygen precipitation nuclei grow oxide precipitates (BMDs) by a heat treatment. Therefore, in order to generate two oxide precipitates (BMDs), at least two oxygen precipitation nuclei are necessary. It is impossible to generate more than two oxide precipitates from one oxygen precipitation nucleus, and if more than two oxide precipitates are generated from one oxygen precipitation nucleus by any possibility, one oxygen precipitation nucleus needs to divide into two oxygen precipitation

nuclei. In this case, ultimately there are two oxygen precipitation nuclei after the division. Therefore, two oxide precipitates are merely generated from two oxygen precipitation nuclei.

However, the oxygen precipitation nucleus cannot divide, as suggested. Applicants have never heard of the oxygen precipitation nucleus dividing, and would welcome evidence thereof.

It is known that occasionally the oxygen precipitation nuclei do not grow but disappear by a heat treatment, or more than two oxygen precipitation nuclei aggregate to form one oxide precipitate. Namely, the density of the oxygen precipitation nuclei become the same with or more than the BMD density which is the concentration of the oxide precipitates. Therefore, it is impossible that the density of the oxygen precipitation nuclei is smaller than the BMD density as the Examiner insists.

2. The Rejection of Claims 1-10 as Unpatentable Over The Various Combinations of References Under 35 U.S.C. 103 (a).

In making these rejections, the statement is made beginning at line 5 of page 14 of the Final Office Action that "The combination of Iida et al. and Fujikawa teaches doping a single crystal with carbon during pulling and controlling the pulling rate and temperature gradient to form an N-region. The increase in pulling rate would have been expected based on the teachings of Iida et al. because the pulling rate is varied between 1.0 mm/min and 0.4 mm/min to determine the outcome of pulling rate for forming an N-region, note Example 1". As further stated on page 14, "Applicants' argument that a person of ordinary skill in the art cannot derive the present invention from Iida in combination with Fujikawa and it is impossible to pullig [sic] a silicon single crystal at a rate greater than the rate of pulling a single crystal with no carbon doping is not persuasive because it is viewed as mere attorney argument, which lacks evidence. Iida et al. teaches varying pulling speed between 1.0 mm/min and 0.4 mm/min to determine the optimum pulling speed for pulling an N-region, note col 14, ln 20-30. The pulling speed

taught by Applicant is 0.63-0.65 mm/min (page 8 of the Remarks), which is within the pulling speed range taught by Iida et al.; therefore the optimum pulling speed to be determined by routine experimentation”.

As further stated at lines 4-9 of page 15 of the Final Office Action, “Applicants’ argument that the pulling rate to obtain the N-region is 0.52-0.54 mm/min is noted but is not found persuasive. Iida et al teaches the pulling rate is 0.52-0.54 mm/min for a specific embodiment and temperature gradient. Iida et al is not limited to this pulling speed, as suggested by applicants. Iida et al also teaches varying pulling speed between 1.0-0.4 mm/min and splitting the grown crystal longitudinally to observe variations in crystal defects to determine the optimum pulling speed for forming an N-region, note Example 1”.

These recitations in the Office Action seem to suggest that in the case of carbon doping, experimental changing of the pulling rate can be carried out, and the optimum pulling rate for forming an N-region should be found by splitting the grown crystal longitudinally, as in the manner of Iida. However, any assumption that the experimental changing of pulling rate is carried out in the case of carbon doping is erroneous.

It is said that the distribution of the crystal defect in the silicon single crystal is determined by the parameter of V/G , which is the ratio of the pulling rate V and the temperature gradient G (see page 4, last paragraph in the specification, lines 50-60 of column 1 of Iida, the claims in Hourai, and so forth). The pulling rate V can be controlled to change freely in the range, for example, of 0.4-1.0 mm/min, as described in Iida, also. However, the temperature gradient G depends on the hot zone structure of the CZ furnace, and is determined by the structure of the furnace used. Therefore, in order for the gradient G to be changed, it is necessary to change the internal structure of the furnace before growing the crystal, and it is almost impossible to control changing of the temperature gradient G during growing of the crystal (see line 41 of column 9 through line 15 of column 10 of Iida, line 59 – last line of column 1 and lines 44-58 of column 4 of Hourai).

Therefore, experimentation by controlling pulling rate V to change, for example, 0.4-1.0 mm/min and observation of the distribution of the crystal defect by splitting the grown crystal longitudinally, may be carried out at only one time with no change of the crystal diameter because the same structures of the furnace have the same temperature gradient G . Because the same internal structure of the CZ furnace can fix the temperature gradient G , the distribution of the crystal defect is determined only by the pulling rate V . Conversely, with no change of the temperature gradient G , the distribution of the defect is determined only by the pulling rate V , and therefore further experimentation of change of the pulling rate as in Iida is meaningless.

Certainly, one of ordinary skill in the art can understand that temperature gradient doesn't change, even though the crystal is doped with very little carbon in pulling. Namely, in doping the crystal with carbon, a person of ordinary skill in the art would have no idea of how to carry out the experimentation to change the pulling rate as in Iida irrespective of there being no change of the temperature gradient G .

Moreover, the experimentation that the pulling rate V is controlled to change, such as for example, 0.4-1.0 mm/min, and the distribution of the crystal defect, is observed by splitting the grown crystal longitudinally. This cannot be done by routine experimentation as suggested in the Office Action. The single crystal ingot grown by the CZ method is not sliced longitudinally to obtain circular silicon single crystal wafers as the products. Therefore, no products can be obtained from the whole single crystal ingot by splitting the single crystal ingot longitudinally. Experimental destruction of an entire very expensive silicon single crystal ingot should not be done without good reason.

On the other hand, doping of the crystal with carbon, as in the case of the present invention, does not change the temperature gradient G . In that instance, the V/G value can be controlled only by the pulling rate V . Therefore, one of ordinary skill in the art would naturally think that a crystal having the desired

defect distribution (here, N-region) can be obtained by the pulling rate V as known in the prior art.

However, and in accordance with the present invention, it is demonstrated that the pulling rate V for the crystal to be N-region can be improved faster than in the case of the prior art by carbon doping, with no change of temperature gradient G . The V/G value for the N-region came to shift by carbon doping in that the pulling rate V for the N-region is changed irrespective of any change of temperature gradient G . The present inventors learned this for the first time, and it would not have been obvious for one of ordinary skill in the art to find this out. Preferably, and as described above, the distribution of the crystal defect is determined by the pulling rate V with no change of temperature gradient G because the distribution of the crystal defect is determined by the V/G value. The present invention defies the conventional wisdom of those skilled in the art that the crystal has a N-region by the same value of the pulling rate V with the prior art if the temperature gradient G does not change. Therefore the knowledge in accordance with the present invention would not be predictable for one of ordinary skill in the art.

It is again emphasized that the pulling rate for the N-region can be improved faster irrespective of there being no change of temperature gradient in the crystal, by doping the crystal with carbon in the case of the present invention. Namely, the V/G value for the N-region shifted.

As previously described, the understanding in accordance with the present invention that the pulling rate for the N-region can be improved faster by doping with carbon means that the V/G value for the N-region shifts by doping with carbon. The temperature gradient doesn't change by doping with carbon, and the pulling rate for the N-region shifts faster irrespective of any change of G , and therefore the V/G value itself to control changes.

For example, and as described at page 15 of the specification, the pulling rate for the N-region with no carbon doping is 0.52-0.54 mm/min. Therefore, and in accordance with the method of Iida, the pulling rate is adequately controlled to be in

the range of such pulling rate, and the crystal of the N-region is pulled with the predetermined V/G value. V/G is made to become such value by controlling the pulling rate adequately.

However, and in accordance with the understanding provided by the present invention, the pulling rate for the N-region shifts to become 0.63-0.65 mm/min by doping with carbon. Therefore, the V/G value to control is changed (here, 0.183 – 0.177 mm³/K·min). It is impossible to control the value to the shifted range because the shift of the V/G value by the carbon doping is unknown in Iida, Hourai, or the other cited references. Because the dopant dependence of the V/G value is not known in such cited references, it is evident that the pulling rate is absolutely intended to control to the same pulling rate V with no carbon doping, and it is impossible to control the shifted pulling rate or the V/G value as in the case of the present invention. This is because changing V with no change of G results in a higher V/G value rather than the desired V/G value. In Iida or in Hourai, making the pulling rate V high with no change of temperature gradient G results, not in an N-region over the entire plane but rather a V-rich region (an infrared scattering defect developing region). This is generated because the V/G value becomes higher (see figures 3, 4 and 10 of Iida and figures 2-5 of Hourai).

Again, and by way of clarification of the misunderstandings evidenced by the statements referred to in the Final Office Action, the present invention makes possible the growing of crystal at a high speed as a result of the shift of the V/G value for the N-region by carbon doping. This is neither shown nor suggested by any of the cited references or by any of the attempted combinations thereof. Therefore, Claims 1-10 are submitted to clearly distinguish patentably over such prior art.

In the Examiner's Response which is set forth in the Advisory Action, Applicants' arguments as set forth above are said not to be found persuasive. Applicants' argument is said to be flawed because Applicants are assuming that doping with carbon does not substantially affect the ability to form an N-region, so

that a person of ordinary skill in the art would perform the process taught by Iida using the parameters, which were determined from an ingot without carbon. Doping with carbon is said not to affect the ability to produce an N-region over the entire wafer, as evidenced by page 15, for example, of Applicants' specification. Applicants are said to teach that the OSF ring disappears at pulling rates greater than 0.65 mm/min and without doping with carbon disappear at 0.54 mm/min, which is similar to the result taught by Iida at lines 45-55 of col. 15 thereof. According to the Examiner, if one of ordinary skill in the art were to perform Iida's process using the parameters taught by such reference to form a carbon doped ingot at the normal pulling speed for forming an N-region over the entire plane, an ingot with an N-region over an entire plane of the crystal would not be formed. Therefore, it would have been obvious to a person of ordinary skill in the art at the time of the invention to modify the combination of Iida et al. and Fujikawa by optimizing the pulling rate to determine the rate required to form an N-region over an entire plane using the method taught by Iida in Example 1.

As further stated by the Examiner in the Response set forth in the Advisory Action, Applicants' argument with respect to the dopant dependency of the V/G value shows that Applicants have recognized another advantage which would flow naturally from following the suggestion of the prior art. This cannot form the basis for patentability when the differences would otherwise be obvious. Performing the operations taught by Iida, Hourai or the other cited references to form an N-region over an entire plane of the wafer would not occur for a carbon doped ingot, as taught by Applicants. Therefore, it is necessary to determine the pulling speed required to determine the value needed to produce an N-region over an entire plane of a crystal doped with carbon by conducting routine experimentation of a result effective variable. As further stated by the Examiner, the fact is that the carbon doped ingot does not form an N-region using the parameters taught by the prior art. The prior art is not restricted to the values disclosed and the prior art teaches a method of determining the optimal pulling speed required. Therefore, the dopant dependents would have naturally flowed from the prior art teachings.

In response to this, Applicants note that the insistences of the Examiner are merely to derive the present invention based on the teachings of the present invention. Inherently, there are neither descriptions nor suggestions in any of the cited references that a silicon single crystal is pulled while doping with carbon to have an N-region over an entire plane of the crystal. It is not described naturally that a V/G value comes to shift in this case. And there are neither descriptions nor suggestions that the V/G value has dopant dependence.

However, the Examiner appears to insist based on only the Applicants' teachings of the present application that a person of ordinary skill in the art finds that the V/G value comes to shift when the silicon single crystal is pulled while doping with carbon to have the N-region over the entire plane of the crystal. Therefore, the Examiner arrives at the teachings of the present application without change and absolutely with the benefit of hindsight. In order to reject the present invention on this basis, it is necessary to identify the reference or references which disclose that the silicon single crystal is pulled while doping with carbon to have the N-region over the entire plane of the crystal.

However, the present inventors were the first to pull the silicon single crystal while doping with carbon so as to have the N-region over the entire plane of the crystal. Therefore, the present invention should not be rejected on the cited references and for the reasons given by the Examiner.

Claim 1 defines a method for producing a silicon single crystal, wherein "the silicon single crystal is pulled while doping with carbon and controlling V/G (V: crystal pulling rate, G: crystal solid-liquid interface temperature gradient along a growing axis) to have an N-region over an entire plane of the crystal". The pulling of the silicon single crystal is "at a rate greater than the rate of pulling a silicon single crystal with no carbon doping". The silicon single crystal "is grown in accordance with Czochralski method". Consequently, Claim 1 is submitted to clearly distinguish patentably over the prior art, taken alone or in the attempted combinations thereof, for the reasons set forth above.

Claims 2-8 depend, directly or indirectly, from and contain all of the limitations of Claim 1 so as to also distinguish patentably over the prior art. In addition, Claim 2 adds doping with nitrogen as well as with carbon. Claims 3 and 4 specify the carbon doping as having a concentration of 0.1 ppma or more as well as controlling V/G within a range of 0.183 to 0.177 mm²/K.min. Claims 5-8 add heat treatment at a temperature of 600 to 1000°C.

Claim 9 defines a silicon wafer "which contains carbon of 0.1 ppma or more and has an N-region over an entire plane thereof". The wafer is defined as having "been pulled at a rate greater than the rate of pulling of a silicon single crystal with no carbon doping". The wafer is still further defined in terms of "in which oxygen precipitation nuclei of 1×10^9 number/cm³ or more are generated by a heat treatment at 600-1000°C thereto". Therefore, Claim 9 is submitted to clearly distinguish patentably over the prior art for the reasons discussed above.

Similar comments apply to Claim 10 which depends from and contains all of the limitations of Claim 9, and in addition, defines the wafer as containing nitrogen of 1×10^{13} number/cm³ or more.

It is therefore respectfully requested that the final rejection of Claims 1-10 be reversed and that such claims be determined to be allowable.

The present Brief is submitted herewith in triplicate along with an Appendix containing the appealed claims and the requisite brief fee.

Respectfully submitted,

HOGAN & HARTSON L.L.P.

By:


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APPENDIX: CLAIMS 1-10 ON APPEAL

Claim 1 (Previously Presented): A method for producing a silicon single crystal, wherein the silicon single crystal is pulled while doping with carbon and controlling V/G (V: crystal pulling rate, G: crystal solid-liquid interface temperature gradient along a growing axis) to have an N-region over an entire plane of the crystal, the silicon single crystal being pulled at a rate greater than the rate of pulling a silicon single crystal with no carbon doping, and in which the silicon single crystal is grown in accordance with Czochralski method.

Claim 2 (Previously Presented): The method for producing a silicon single crystal according to claim 1, wherein the silicon single crystal is doped with nitrogen as well as carbon in which the CZ silicon single crystal is grown.

Claim 3 (Previously Presented): The method for producing a silicon single crystal according to claim 1, wherein the silicon single crystal is pulled while doping with carbon having concentration of 0.1 ppma or more and controlling V/G within a range of 0.183 to 0.177 mm²/K·min.

Claim 4 (Previously Presented): The method for producing a silicon single crystal according to claim 2, wherein a silicon single crystal is pulled while doping with carbon having concentration of 0.1 ppma or more and controlling V/G within a range of 0.183 to 0.177 mm²/K·min.

Claim 5 (Previously Presented): A method for producing a silicon single crystal, wherein the silicon single crystal produced by the method according to claim 1 is processed into wafers, and the wafers are subjected to heat treatment at a temperature of 600 to 1000°C.

Claim 6 (Previously Presented): A method for producing a silicon single crystal, wherein the silicon single crystal produced by the method according to claim

2 is processed into wafers, and the wafers are subjected to heat treatment at a temperature of 600 to 1000°C.

Claim 7 (Previously Presented): A method for producing a silicon single crystal, wherein the silicon single crystal produced by the method according to claim 3 is processed into wafers, and the wafers are subjected to heat treatment at a temperature of 600 to 1000°C.

Claim 8 (Previously Presented): A method for producing a silicon single crystal, wherein the silicon single crystal produced by the method according to claim 4 is processed into wafers, and the wafers are subjected to heat treatment at a temperature of 600 to 1000°C.

Claim 9 (Previously Presented): A silicon wafer, which contains carbon of 0.1 ppma or more and has an N-region over an entire plane thereof, which has been pulled at a rate greater than the rate of pulling a silicon single crystal with no carbon doping, and in which oxygen precipitation nuclei of 1×10^9 number/cm³ or more are generated by a heat treatment at 600-1000°C thereto.

Claim 10 (Original): The silicon wafer according to claim 9, which contains nitrogen of 1×10^{13} number/cm³ or more.